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Engineering and Quality Assurance Cost Factors Associated with Nuclear Plant Modification

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United Engineers and Constructors

Prepared for
U.S. Nuclear Regulatory Commission

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Engineering and Quality Assurance
Cost Factors Associated with
Nuclear Plant Modification

I. SUMMARY AND CONCLUSIONS

1. Introduction

Many pending and proposed Nuclear Regulatory Commission (NRC) regulations will result in physical modifications to nuclear facilities. In these instances, a licensee will incur engineering and quality assurance costs[a] associated with the modification or repair. The NRC Cost and Statistical Analysis Staff (CSAS) has sponsored this study to assist NRC analysts in the estimation of engineering and quality assurance costs for inclusion in regulatory impact analyses.

In this study, new and existing data have been developed and analyzed to produce generic cost estimates of engineering and quality assurance (QA) costs. The estimates are not absolute dollar values but rather are cost factors which are expressed as a percentage of the direct cost (equipment, materials, and labor) of implementing the plant modification.

The above mentioned cost factors can vary significantly depending on the work environment at the time the modification is implemented, and the nature of the modification. A discussion of these two influences follows:

2. Work Environment

In general, for a given modification, the dollar cost of engineering/QA is largely independent of the work environment. It is only when engineering/QA costs are to be estimated as a function of direct costs that consideration of the environment becomes important. The work environment can have a significant effect on the direct cost of implementing the change. For example, many physical modifications performed at existing plants involve rework, congestion, access and handling problems, and work constraints associated with a radiation environment. The conditions translate into much higher direct costs to perform modifications than occur under a new construction environment where work can be performed under more idealized conditions. Thus, for modifications effecting structures and systems

(a) Engineering/QA cost, as used throughout this report, represents Home Office Engineering and Services cost only, which is defined in Account 92 of the Energy Economic Data Base (EEDB). See Section IV of this report for a description of this account. It should be noted that Field Office Engineering and Services cost, Account 93 of the EEDB, is not included as it is considered insignificant for most modifications made to operating plants. For modifications to future plants and for select modifications to operating plants (modifications performed in a new construction environment) field office engineering and QA may be important. Guidance to adjust for this, is provided in this report.

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already in place at operating and near complete plants, the engineering/QA cost estimating factor will be relatively low, as a percentage of the higher direct cost of making a repair or modification at such a plant. Alternatively, for requirements that involve the addition of structures and systems in a new construction environment, the engineering/QA cost estimating factor will be relatively high because of the lower direct cost. This higher cost factor would typically apply to work performed at future plants, plants at the early stages of construction, and operating plants where new requirements are independent and separate from the operating plant.

A description of the two general types of work environments which are the basis for differentiating engineering/QA cost factors, are described below:

2.1 Category Descriptions

- Requirements Affecting Structures and Systems Already In-Place... Applicable to Operating Plants and Plants Under Construction(b)

  Modifications are typically difficult to implement in plants which are nearing commercial operation and in operating units. The difficulty of implementation, results from such things as congestion, radiation and the shielding and safety concerns associated with exposure, and the problems of security. The combination of these factors has a direct affect on the productivity of craft labor and tends to make the overall cost of the modification higher than that of new construction. Since the direct cost of a change can conceivably be many times higher than the cost of new construction, the engineering/QA cost is a lower percentage of direct costs.

  For these types of modifications, most of the engineering is accomplished in the home office. Field Office Engineering and Service costs are a rather small part of the total engineering cost and are not included in developing the cost factors in this study.

- New Construction Requirements... Applicable to Future Plants, Plants Under Construction(c), and Operating Plants(d)

  Engineering and QA requirements for modifications to future plants and plants at early stages of construction can typically be accomplished as part of the overall initial design process. The modifications are easily implemented as they require no tear outs or modifications to existing structures and systems. For this type of change, the direct cost tends to be lower, and the engineering/QA cost, as a percentage of the direct cost, will be higher than for modifications to existing structures and systems.

(b) As a general rule, represents those plants nearing completion (typically > 70% complete).
(c) As a general rule, represents those plants in early stages of construction (typically < 70% complete).
(d) For additions that are independent and separate from the operating plant.

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New construction requirements for future plants will involve a large field office engineering and QA effort that is not accounted for in the engineering/QA cost factors developed in this study. However, given the current status of the U.S. nuclear power industry relative to new orders, and plants in early stages of construction, impacts to future plants are perceived as of minimal significance and are typically not addressed in NRC regulatory impact analyses. In the event impacts to future plants are of importance, it is reasonable to expect a field office effort of approximately the same magnitude as the home office effort. Thus, in these instances, the engineering/QA cost factors presented in this report should be doubled.

Certain modifications to operating plants may involve new structures whose construction is in no way impeded by the existence of an operating reactor at the site. In these circumstances, the engineering/QA cost factor would be similar to that of new construction type modifications, where the home office engineering effort has a field counterpart of approximately the same magnitude and thus, a similar adjustment would be required. However, there will be instances of new construction at operating plants where home office engineering represents most of the total engineering effort for modifications. In these cases, the analyst will need much more defined knowledge of the modifications to be performed.

3. Types of Modification

The cost factors developed in this study capture the engineering/QA costs associated with physical modifications to the structures/systems of nuclear power plants. In contrast to this type of modification is an analytic or procedural change. Engineering and QA costs for procedural changes can be extensive even though there is little or no physical change to the plant. However, the cost factors developed herein are a function of the direct cost of a physical change, and thus will not be useful for analytic/procedural requirements. For guidance in estimating the engineering/QA costs for non-physical requirements the reader is referred to NUREG/CR-3971 entitled "A Handbook for Cost Estimating." Section 6.5 of this Cost Handbook provides an example cost estimate that directly computes engineering and QA costs as a function of labor effort and labor rate for each significant work package (functional response) associated with a new requirement. This illustrative approach can be followed for those requirements that do not involve a physical modification to the plant.

For physical modifications to existing structures/systems, the engineering/QA cost factors are generic across all modifications that are moderate to extensive in nature. This is because the data are insufficient to differentiate these costs on a specific structure or system basis. However, a range of observed values is presented, and values toward the low end of this range should be considered for modifications involving the installation of off-the-shelf items requiring a minor amount of engineering. Alternatively, for many relatively minor, low-cost modifications, values towards the high end of the range should be considered because even a de minimis engineering effort could be large as a percentage of the direct cost.

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For physical modifications performed in a new construction environment, generic engineering/QA cost factors are similarly provided and the same basis for adopting values at the low to high end of the range is also operative. In addition, engineering/QA cost factors are provided on a structure/system-specific basis. The use of these more specific values is predicated on an NRC analyst being able to allocate the direct costs among the specific structures and systems that will be affected in accordance with the Energy Economic Data Base (EEDB) code-of-accounts.

4. Results

The results of the analysis are summarized in Tables 1 and 1A. In Table 1 generic estimates are presented for the engineering/QA as a percentage of the direct cost for a) physical modifications to existing structures and systems, and b) physical modifications performed in a new construction environment. The results are based on several different data sources, and consist of medians, which were developed using statistical measures, where appropriate. The medians, which represent the 50^{th} percentile of samples, were chosen because averages or means would have been skewed by some exceptionally high and low values.

For modifications to existing structures and systems, four data sources, Tables 2, 3, 4 and 5, focusing on costs at operating reactors, were evaluated. One of the sources, Other Electric Utilities' Cost Data, Table 5, contains considerably more cost information than the other three sources. However, the degree of confidence in this data source was not as great as for the other three. Therefore, it was decided to evaluate these data sources in two ways. The first consisted of developing a median for each of the four data sources, and then a single median for the four medians, based on equal weighting. This resulted in individual medians ranging from 9% to 29%, and a single median of 22%, as shown in Table 1. The second way consisted of combining the operating plant cost data from all four sources and identifying the median from that one enlarged data set. The resulting median of 27%, as shown in Table 1, is heavily influenced by the large number of data points included in Table 5, Other Electric Utilities Cost Data. The overall recommended point estimate is the approximate median of both approaches.

For new construction at future and existing plants, three sources of data, Tables 1A, 6 and NUREG/CT-3971 were evaluated. These data show reasonably good agreement with median values ranging from 29 to 38 percent.

Table 1A provides results from the EEDB program. These cost factors allow for the differentiation of engineering/QA cost as a function of the specific structure/system affected. The results can be used for estimating engineering/QA costs for work performed in a new construction environment, and require that the analyst have a good sense of the specific structures/systems affected. They are also only applicable when the proposed modification entails moderate to extensive additions. Table 1A summarizes these percents at the two-digit level of detail. These cost factors (rounded off) range from 19 percent to 38 percent for the various direct cost categories, and are indicative of the sensitivity of costs to the specific structure/system affected. In Section IV, Table 8, of this report, structure/system-specific cost factors are presented at the three-digit level of detail. These values offer the potential of even greater accuracy

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TABLE 1

ENGINEERING/QUALITY ASSURANCE COSTS AS A PERCENTAGE OF THE DIRECT COST OF MODIFICATIONS

WORK ENVIRONMENT IN WHICH MODIFICATION IS PERFORMED	DATA SOURCES	ENGINEERING/QUALITY ASSURANCE[1] COST FACTOR (PERCENT)		
		INDIVIDUAL MEDIANS	MEDIAN OF MEDIANS	RECOMMENDED POINT ESTIMATE[4]
REQUIREMENTS AFFECTING STRUCTURES/SYSTEMS ALREADY IN-PLACE				
OPERATING PLANTS	SANDIA STUDY	9		
	UTILITY SURVEY DATA	15	22	
	OTHER ELECTRIC UTILITIES COST DATA	28		
	NORTHEAST UTILITIES COST DATA	29		25
	ALL OPERATING PLANTS COST DATA COMBINED	27	27	
NEW CONSTRUCTION REQUIREMENTS				
-- FUTURE PLANTS	EEDB VII[2][5]	30		
-- EXISTING PLANTS	NUREG/CR-3971[3][5]	38	30	30
	SANDIA[5] STUDY	29		

Footnotes

1. These cost factors are to be applied to the direct cost of a physical modification. If requirement is analytic or procedural in nature, reader is referred to NUREG/CR-3971 for calculating engineering content directly, as discussed in Section I.3 of this report.
2. See Tables 1A and 8 for engineering/QA costs based on EEDB two-digit and three-digit level of detail.
3. Technical Support Center example, pp. 106-136 of NUREG/CR-3971
4. Generic point estimates of 25 and 30 percent correspond to the medians of the respective median values of the data used.

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TABLE 1
(continued)

ENGINEERING/QUALITY ASSURANCE COSTS AS A PERCENTAGE
OF THE DIRECT COST OF MODIFICATIONS

5. These cost factors exclude the engineering/QA effort conducted by a field office. If a large field office operation is established to support the home office engineering/QA effort, costs can be significantly higher, and a doubling of these cost factors is suggested. This adjustment would likely be applicable to requirements impacting future plants, and for select modifications to existing plants where the work is performed in a new construction environment. In these instances, more detailed specific knowledge of the modification would be required to make this determination.

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TABLE 1A

ENGINEERING AND QUALITY ASSURANCE
AS A PERCENT OF THE
DIRECT COST OF MODIFICATIONS

EEDB VII-NEW CONSTRUCTION

ACCOUNT NO.	DESCRIPTION OF DIRECT COST	ENGINEERING/QA PERCENT
21	Structures & Improvements	37
22	Reactor Plant Equipment	33
23	Turbine Plant Equipment	19
24	Electric Plant Equipment	28
25	Miscellaneous Plant Equipment	38
26	Main Condenser Heat Rejection System	19
	TOTAL DIRECT COST	30

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TABLE 2*

UTILITY SURVEY DATA

PLANT	TYPE	COMMERCIAL OPER DATE	NRC IMPOSED MODIFICATION	BEGIN DATE	END DATE	ACCOUNTS	SEISMIC CAT1	SEISMIC CAT2	SAFLTY CLASS1	SAFETY CLASS2	ENV1	ENV2	ENG1	ENG2	QC	ENG/QA % OF DIRECT INSTAL COST	DIRECT INSTAL COST
1	PUB	12/21/76	NUREG 737 POST ACC SAMP SYS	9/81	1/82	SBI BPE NPE	S1		S		B	NB	AE	V	U	3%	750,000
1	PUB	12/21/76	NUREG 737 CONTAIN ISOLATION	12/80	12/85	BPE EPE	S1	NS1	S	NS	B		AE	V	U	17%	17,000,000
.	PUB	12/21/76	SEC 10CFR73 PERIM ALARM SYS	1982	1983	SBI EPE	NS1		S		B	NB	AE	U	U	31%	2,100,000
1	PUB	12/21/76	SP FUEL PL EXP,FUEL PL RERACK	1/86	7/87	BPE EPE	S1		S		B		AE		U	13%	8,000,000
1	PUB	12/21/76	ENV QUALIF EQUIP REPLACEMENTS	2/83	9/85	BPE EPE										46%	2,000,000
1	PUB	12/21/76	FIRE PROTECTION (APPENDIX R)	11/81	6/86	SBI BPE EPE	S1	NS1	S		B	NB	AE	U	U	36%	16,700,000
2	PUB	1960	NUREG 737 CNTRL RM HABITABIL	1980		SBI BPE EPE	S1		S		NB		U		U	14%	4,650,000
2	PUB	1960	REPLACE CONTAINMENT ELEC PEN	4/79	7/80	SBI BPE EPE	S1		S		B		U		AE	11%	3,703,000
2	PUB	1960	EMERG OPER CTR TMI ITEM : 2 2	10/79	12/80	SBI BPE EPE	S1		S		NB		U		U	10%	2,010,000
2	PUB	1960	REACTOR BD AREA CABLE SUPP STR	11/81	4/83	BPE EPE	S1		S		B		U		U	10%	4,499,000
3	BUR	1970	NUREG 80-17 SCRAM DSCH VOL MOD	1980	3/83	BPE EPE	S1		S		B		U		U	11%	3,373,000
3	BUR	1970	PROCESS COMPUTER REPLACEMENT	6/80	1980	SBI BPE EPE	NS1				NB		AE	U	U	29%	12,136,100
3	BUR	1970	SOLID R-ACTIVE WASTE DISP SYS	1980	10/84	BPE EPE	S1		S		B		U		U	20%	1,490,038
3	BUR	1970	SOLID WASTE PROCESS SYS MOD'S	1980	12/84	BPE EPE	NS1		NS		B		U		U	24%	989,377
3	BUR	1970	SOLID RADWASTE STORAGE BLDG	1979	1980	SBI BPE EPE	NS1		NS		NB		U		U	15%	910,031

*These cost data and associated cost factors are based on United Engineers' survey of electric utilities.

TABLE 2 (Cont'd)

*Description of Column Headings

- o ACCOUNTS - Identifies location of where the modification was performed, based on the EEDB system/structure two-digit accounts.
- o SEISMIC CATEGORY 1 & CATEGORY 2 - Identifies seismic classification of system/structure that was modified, in terms of Seismic Category 1 or Non-Seismic Category 1.
- o SAFETY CLASS 1 AND CLASS 2 - Identifies safety classification of system/structure that was modified, in terms of Safety or Non-Safety
- o ENV 1 AND ENV 2 - Identifies environment where the modification was performed, in terms of Radioactive or Non-Radioactive
- o SEISMIC, SAFETY AND ENV headings each have two columns, to accommodate the identification of modifications that include more than one system/structure and classification.
- o ENG 1 AND ENG 2 - Identifies the major supplier of the engienering service, in terms of Architect/Engineer, Utility or Vendor. Two columns are shown for modifications that include more than one engineering source.
- o QC - Identifies the major supplier of the quality control service, in terms of Architect/Engineer, Utility or Vendor
- o See Appendix to Section II (Instructions for Questionnaire and Questionnaire) for further descriptions of column headings and data entries.

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TABLE 3

SANDIA STUDY**

SHUTDOWN DECAY HEAT REMOVAL REQUIREMENTS
(NUREG-0606, USI A-45)
PROPOSED MODIFICATIONS IN OPERATING PLANTS

PLANT FACILITY	PLANT TYPE	MODS	H.O. ENGR./QA COST ($000's)	DIRECT COST ($000's)	ENGR./QA COST AS % OF DIRECT COST	ACCOUNTS* AFFECTED
1	PWR	1	74	1,017	7	RPE, EPE
		2	88	1,368	6	RPE, EPE
2	PWR	2	189	4,759	4	RPE, EPE
3	PWR	2	267	3,096	9	RPE, EPE
		4	322	3,950	8	RPE, EPE
4	PWR	1	377	4,418	9	RPE, EPE
		2	829	8,069	10	RPE, EPE
		3	1,389	12,480	11	RPE, EPE
5	BWR	2	255	1,589	16	RPE, EPE
		3	255	1,529	17	RPE, EPE
		4	134	1,305	10	RPE, EPE

MEDIAN = 9%

* From EEDB-Phase VII Code-of-Accounts
RPE - Reactor Plant Equipment
EPE - Electric Plant Equipment

** This data and associated cost factors are based upon cost data developed by United Engineers for Sandia, in support of their program to provide solutions to unresolved safety issue A45, "Decay Heat Removal."

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TABLE 4

NORTHEAST UTILITIES COST DATA

MILLSTONE UNIT NO. 1
BETTERMENT PROJECTS

PA#	TITLE	DIRECT COST	ENG/QA COST	ENG/QA COST%
80-014	Solid Rad Waste Mods	$1,450,596	420,559	29%
80-037	Feedwater Reb. Vlv. Improv.	283,645	203,258	72%
80-135	Under Voltage Protection	138,222	167,294	121%
80-211	Replacement of MOVs	276,026	253,748	92%
80-239	Replace 1-RC-39	61,213	57,536	94%
81-106	Appendix J Modifications	223,901	151,244	68%
82-040	Reg. Volt Transformer	267,209	28,064	11%
82-099	Steam Tunnel Leak Protection	24,399	42,373	174%
82-220	Rad Waste Reduction Fac	439,450	203,163	46%
83-017	Drywell Ventil. System	45,858	59,850	131%
83-018	Rx Feed Pump Min Flows Vlvs.	254,664	76,492	30%
83-063	Neutron Battery Rep.	48,626	13,287	27%
83-068	Station Battery Replacement	4,932	5,803	118%
83-078	Extraction Steam Pipe	3,832,693	260,201	7%

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TABLE 4 (Cont'd)

NORTHEAST UTILITIES COST DATA

MILLSTONE UNIT NO. 2
BETTERMENT PROJECTS

PA#	TITLE	DIRECT COST	ENG/QA COST	ENG/QA COST%
80-015	Solid Rad Waste Mods	$ 887,108	235,996	27%
80-171	Replace Rosemount RTD's	846,689	170,117	20%
82-071	MS&FD Pipe Suppt.	3,363,681	245,893	7%
82-149	Proc. Cab & Feedwater Sys.	360,092	143,213	40%
82-157	React. Cont. Indication System	148,491	40,630	27%
83-075	Pzr. Press & Level Inst.	187,146	54,481	29%

TABLE 4 (Cont'd)

NORTHEAST UTILITIES COST DATA

CONNECTICUT YANKEE
BETTERMENT PROJECTS

PA#	TITLE	DIRECT COST	ENG/QA COST	ENG/QA COST%
80-087	RMC CY Spare Gen. Step-Up Transformer	$2,206,488	358,512	16%
80-109	Add Instr. ICC	4,180,383	934,617	22%
80-201	Replace Motor Oper.	583,455	211,545	36%
81-057	Safety Related Piping-Phase2	964,127	248,873	26%
82-080	Stm. Gen. Manway Tensioner	827,767	140,233	17%
83-105	Curbs, Ramps, Seals, Shields	873,168	153,832	18%
83-120	Control Room Halon System	527,566	226,434	43%
83-123	Fire Protection Imp. A3/A4	46,886	31,114	66%
84-106	FW Htr. Relmt.	1,066,339	212,661	20%
84-138	Evaluation of Alt. Pool Seal Des.	910,970	234,030	26%
85-024	Waterbox A Retubing	814,472	127,528	16%

* These cost data were provided by Northeast Utilities, and are based on their nuclear plant experience.

MEDIAN FOR ALL PROJECTS: 29%

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TABLE 5

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./QA COSTS	ENG./QA COSTS %	RANKING
Turbine Building Roof Vent. Modifications	189,000	372,800	197.25%	1
Replace Moisture Separator Reheater (MSR) Tube Bundles	19,000	36,800	193.68%	2
Relief Valve Blowdown Control	1,084,000	2,062,400	190.26%	3
Small Bore Pipe and Hangers	3,584,000	6,704,000	187.05%	4
Recirculation System Piping Replacement	16,263,000	30,171,200	185.52%	5
Radiation Dose Assessment Computer System	191,800	352,960	184.03%	6
Fire Protection	7,000,000	12,800,000	182.86%	7
Quench Tank Drain Pump	113,000	192,000	169.91%	8
Alternate Remote Shutdown Panel	185,000	300,800	162.59%	9
Torus Temperature Monitor	817,000	1,322,720	161.90%	10
Replace Reactor Vessel Interal Bolts	2,062,000	3,307,200	160.39%	11
Electropolish ID/New Recirculation Pipe	438,000	683,200	155.98%	12
Fire Protection Modification	2,283,800	3,380,160	148.01%	13
Upgrade Non-Nuclear Instrumentation (NNI) Power Supply	492,000	726,400	147.64%	14
Sodar Meterological Data System	232,000	342,400	147.59%	15
Reactor Water Level Measurement Improvement	635,000	904,000	142.36%	16
Modify Concrete Block Walls	3,651,000	5,187,200	142.08%	17
Blume Criteria Support Documentation	3,800,000	5,120,000	134.74%	18
Design and Installation of AMSAC System	599,000	800,000	133.56%	19
Piping Verification	18,843,000	23,411,200	124.24%	20
Radwaste System Phase B Modifications	1,117,900	1,366,560	122.24%	21
Powerplex	2,940,500	3,581,440	121.80%	22
Fire Hazards Analysis Update	2,600,000	3,040,000	116.92%	23
Low-Level Radwaste Storage/Shipping Building	1,182,300	1,377,920	116.55%	24
Review Control Room Design	1,795,000	2,076,800	115.70%	25
SPDS Enhancements	786,100	876,640	111.52%	26
Install Reactor Coolant System Level Monitoring Equipment	2,416,000	2,649,600	109.67%	27
Rod Worth Minimizer Replacement	475,000	520,000	109.47%	28
IHSI - New Recirculation, RHR, Core Spray Pipe Joints	1,899,000	2,009,600	105.82%	29
Install Reactor Coolant System (RCS) Post Accident Sampling System	3,372,000	3,550,400	105.29%	30
Scram Discharge Volume Modification	3,550,000	3,680,000	103.66%	31
Nuclear Services Electrical Building	11,165,000	11,472,000	102.75%	32
Control Room Habitability	508,100	517,920	101.93%	33
Install Equipment to Contain Secondary Side Contamination	1,162,000	1,171,200	100.79%	34
Simulator Facility Addition	68,000	65,600	96.47%	35
Post-Accident Monitoring	3,020,000	2,832,000	93.77%	36
Steam Generator Protection Unit 3&4	25,734,000	23,625,600	91.81%	37
Post LOCA Combustable Gas Control System	5,374,000	4,833,600	89.94%	38
Replace Radwaste Tanks & Piping System	5,080,000	4,560,000	89.76%	39
Install Reactor Coolant System Monitoring Equipment	1,417,000	1,260,800	88.98%	40
Nozzle Shielding Replacement	315,000	280,000	88.89%	41
Control Rod Drive Maintenance Room	815,200	693,760	85.10%	42
Fire Protection	1,220,000	1,056,000	86.56%	43
Emergency Diesel Generators Facility	14,607,000	12,513,600	85.67%	44
Appendix "R" Fire Barrier Upgrade	1,847,000	1,556,800	84.29%	45
Modify Blowdown Piping for Once Through Steam Generator	3,363,000	2,800,000	83.26%	46
Implement Results of As Built Verification	16,500,000	13,600,000	82.42%	47
Modify Piping Hanger/Anchor Supports	22,007,000	18,036,800	81.96%	48
Torus Attached Piping & Support Modifications	10,900,000	8,800,000	80.73%	49

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TABLE 5 (cont.)

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./QA COSTS	ENG./QA COSTS %	RANKING
Process Computer Replacement	5,454,000	4,401,600	80.70%	50
Modify Spent Resin Storage/Transfer System	1,062,000	843,200	79.40%	51
ESW Keep Fill	115,300	91,200	79.10%	52
Replace Refuiling Platform	630,000	483,200	76.70%	53
Existing 250V Battery Charger Upgrade	261,000	200,000	76.63%	54
ATWS Alternate 3	200,000	152,000	76.00%	55
Modify Piping Hanger/Anchor Supports	23,215,000	17,262,400	74.36%	56
ESW - Spray Ponds (Freeze Problem)	1,326,000	976,320	73.63%	57
Emergency Diesel Generator "E"	52,105,000	37,736,000	72.42%	58
Modify Circulating Water Intake and Discharge	13,334,000	9,408,000	70.56%	59
HPCI Vacuum Breaker Line	711,000	496,000	69.76%	60
Replace Feedwater Heaters 13A and B	1,735,000	1,208,000	69.63%	61
Postaccident Monitoring Instrumentation	145,000	100,800	69.52%	62
Tritium Handling Facilities	2,879,000	2,000,000	69.47%	63
Reactor Water Cleanup Modification	1,245,000	859,200	69.01%	64
Flood Protection Project	119,000	81,600	68.57%	65
Radwaste Phase C	1,748,100	1,163,040	66.53%	66
Process Computer Replacement	12,136,000	8,072,000	66.51%	67
Additional Meteorological Towers	173,000	113,760	65.76%	68
On-Site Radwaste Storage Facility	7,800,000	5,120,000	65.64%	69
Nitrogen Makeup	398,100	259,040	65.07%	70
Vessel Nozzle Weld Requirements	1,017,000	651,200	64.03%	71
Reactor Water Cleanup Modification	1,294,000	824,000	63.68%	72
Condensate Demineralizer Modification	1,873,900	1,183,520	63.16%	73
Transmitter Installation Valve & Cable Relocation	4,220,000	2,652,800	62.86%	74
SPDS Enhancements	946,000	588,800	62.24%	75
Emergency Coolant Injection System	58,317,000	35,748,800	61.30%	76
Fire Protection Appendix "R" Modification	12,802,000	7,836,800	61.22%	77
Modify Blowdown Piping for the Once Through Steam Gen.	3,175,000	1,926,400	60.67%	78
Modify Service Water System	2,779,000	1,667,200	59.99%	79
Fire Protection Safe Shutdown Modifications	6,075,000	3,640,000	59.92%	80
Digital Feedwater Control System Modification	802,000	480,000	59.85%	81
Steam Generator Protection	18,806,000	11,190,400	59.50%	82
Heavy Loads Analysis	822,000	484,800	58.98%	83
Fire Protection Appendix "R" Modification	12,800,000	7,520,000	58.75%	84
ATWS Modification-ARI-SLCS	2,325,000	1,360,000	58.49%	85
Drywell Cooling Modifications	3,820,000	2,208,000	57.80%	86
Digital Reactor Protection System Improvement	1,385,000	800,000	57.76%	87
Modify Fire Protection System	19,188,000	10,913,600	56.88%	88
ESW - Water Hammer	1,580,000	896,000	56.71%	89
Technical Support Center	1,657,000	929,600	56.10%	90
Fire Protection Modifications to Meet Appendix "R".	11,115,000	6,192,000	55.71%	91
Computer, Plant Process System	9,577,000	5,300,800	55.35%	92
Emergency Coolant Injection System	36,780,000	20,160,000	54.81%	93
ESW Single Failure	769,800	416,000	54.04%	94
Radiological Information Management System	950,000	507,200	53.39%	95
Anticipated Transient Without Scram System	450,000	240,000	53.33%	96
Vent Stack Monitors	2,472,200	1,276,480	51.63%	97
Appendix "R" Structural Steel Fire Protection	466,000	240,000	51.50%	98

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TABLE 5 (cont.)

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./OA COSTS	ENG./OA COSTS %	RANKING
Hydrogen Water Chemistry	3,200,000	1,600,000	50.00%	99
ESW - HPCI Alternate Room Cooling	373,000	184,000	49.33%	100
New Cable Spread Room	16,010,000	7,488,000	46.77%	101
Drywell Ventilation System Improvement	5,860,000	2,736,000	46.69%	102
HVAC System for Control Room Habitability	8,250,000	3,840,000	46.55%	103
Service Building Addition	2,511,700	1,141,120	45.43%	104
Control Room Habitability	591,000	267,200	45.21%	105
Post Accident Sampling	6,200,000	2,720,000	43.87%	106
Feedwater Sparger Replacement	867,000	371,200	42.81%	107
Drywell Ventilation System	769,000	324,800	42.24%	108
Site Security	9,347,000	3,923,200	41.97%	109
Low-Level Radwaste Storage Building	822,000	344,000	41.85%	110
Offsite Dose Computation	1,380,600	571,360	41.38%	111
Valve Replacement II	1,940,000	800,000	41.24%	112
St. Lucie Unit 1 Fire Protection, 10 CFR 50 Appendix "R"	15,176,000	6,118,400	40.32%	113
Turbine Rotor Storage Building and Spur	203,700	79,520	39.04%	114
Trash Compaction Building	1,245,000	480,000	38.55%	115
Recirculation & RHR Pipe Replacement	50,000,000	19,200,000	38.40%	116
Engineered Safeguard System (ESS) Transformer Addition	2,500,000	960,000	38.40%	117
Upgrade Emergency Diesel Generator System	1,243,000	467,200	37.59%	118
Expand Maintenance Shop Areas	342,000	128,000	37.43%	119
SIRW Tank Foundation	4,621,000	1,726,400	37.36%	120
Radwaste Crystalizer	8,640,000	3,200,000	37.04%	121
Elimination of RTD Bypass Manifolds	1,354,000	480,000	35.45%	122
Yard Drainage Control	491,000	171,200	34.87%	123
Security & Radiation Exposure and Maintenance System	10,485,000	3,632,000	34.64%	124
Fire Wall Addition	37,600	12,800	34.04%	125
Service & Administration Building - Phase B	6,454,200	2,163,040	33.51%	126
ATWS	2,523,300	842,720	33.40%	127
Appendix "R" Analysis & Modification	3,604,000	1,190,400	33.03%	128
Analog Trip System	3,970,000	1,280,000	32.24%	129
Offgas System Improvements	10,638,000	3,419,200	32.14%	130
Interim Onsite Storage Building	5,515,000	1,760,000	31.91%	131
Expanded Safety Systems Facility	48,405,000	15,064,000	31.12%	132
Radwaste System Improvements	890,000	272,000	30.56%	133
Modify Radiation Monitoring Systems	8,624,000	2,633,600	30.54%	134
Drywell Cooling Modifications	2,118,000	643,200	30.37%	135
Anchorage of Safety Related Electrical Equipment	828,000	247,200	29.86%	136
Condensate Polisher	3,300,000	960,000	29.09%	137
Pickering Administration Building	8,756,000	2,518,400	28.76%	138
Radwaste Phase D	17,137,000	4,892,800	28.45%	139
Radiation Monitoring	15,650,000	4,400,000	28.12%	140
Simulator Building	1,315,000	366,400	27.86%	141
Indian Point #2 - Condenser Vacuum	580,100	161,440	27.83%	142
Cooling Tower Bypass - Unit 1	1,450,000	400,000	27.59%	143
Central Control Room HVAC Upgrade	286,000	78,720	27.52%	144
Hot Machine Shop	4,519,000	1,224,000	27.09%	145
Drywell Equipment Drain Tank Modification	1,683,000	456,000	27.09%	146
Training and Records Building	5,555,000	1,504,000	27.07%	147

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TABLE 5 (cont.)

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./DR COSTS	ENG./DA COSTS %	RANKING
Replace Station Computer Multiplexers	1,746,000	470,400	26.94%	148
Safety Assessment System Computers	12,281,000	3,284,800	26.75%	149
Feedwater Heater Replacement	1,843,000	492,800	26.74%	150
Hydrogen Water Chemistry	10,135,000	2,707,200	26.71%	151
COLSS Back-up Computer System	4,290,000	1,136,000	26.48%	152
Circulating Water Pumps and Water	8,672,100	2,282,560	26.32%	153
Spare Auxiliary Transformer	537,000	140,640	26.19%	154
Boiler Feed Pumps	195,500	51,200	26.19%	155
Holdup Tanks Vent System	540,000	140,800	26.07%	156
Partial Replacement of Turbine Steam Extraction Piping	1,084,000	280,000	25.83%	157
RHR Piping Heat Exchanger	725,000	187,200	25.82%	158
Flow Measuring Orifices for Pumps	838,000	216,000	25.78%	159
Steam Drain Piping	425,300	109,440	25.73%	160
ATWS	2,521,100	646,240	25.63%	161
Condenser Tube Inserts & Coating	2,144,000	547,200	25.52%	162
Cond, FW, Reactor Water Sampling & Analysis	950,000	240,000	25.26%	163
Control Room Habitability	5,590,000	1,411,200	25.25%	164
Off Gas Management	3,241,000	817,600	25.23%	165
Motor Control Center No. 28A	406,000	102,400	25.22%	166
Uninterruptible Power Supply	725,000	182,400	25.16%	167
Office and Power Stores Facility	34,760,000	8,721,600	25.09%	168
Pressure Switches, Trips & Flow Pressure Indicators	351,000	88,000	25.07%	169
Site Security	6,688,000	1,619,200	24.21%	170
Turbine Supervisory Instruments	1,113,200	269,280	24.19%	171
Leading Edge Flow Meter System	1,418,000	342,400	24.15%	172
I & E Area Renovation	757,000	180,800	23.88%	173
Reactor Water Feedpump Modifications	1,758,000	417,600	23.75%	174
Contract Services Building	844,000	196,800	23.32%	175
Auxiliary Feedwater System Upgrade	1,750,000	400,000	22.86%	176
Replacement of Refuel Bridge	1,081,000	246,400	22.79%	177
Operational Support Facility	3,970,000	856,000	21.56%	178
Upgrade Weld Shop	104,000	22,400	21.54%	179
Auxillary Power Upgrade Phase II	20,790,000	4,352,000	20.94%	180
Respiratory/Service Air System	2,490,000	496,000	19.92%	181
Replace 8th Stage Feedwater Heaters	1,226,000	241,600	19.71%	182
Interim On-Site Storage for Low-Level Radwaste	1,587,900	310,400	19.55%	183
Install Moisture Separator Reheater (MSR) Drain Demineralizer	1,247,000	241,600	19.37%	184
Radiation Monitoring System	1,801,000	345,600	19.19%	185
Spent Fuel Storage Rack Modification	1,735,000	332,800	19.18%	186
Scram Discharge Volume Modifications	3,575,000	680,000	19.02%	187
Security Intrusion Alarm Detection	3,467,000	659,200	19.01%	188
Simulator Facility Additions	101,600	19,200	18.90%	189
Sewage Treatement Plant	423,100	79,840	18.87%	190
Thermal Margin/Low Pressure Trip Circuit Upgrade	1,057,000	196,800	18.62%	191
Reg. Guide 1.97 - Unit 1	6,576,000	1,220,800	18.56%	192
Core Cooling Instrumentation	5,825,000	1,080,000	18.54%	193
Turbine Maintenance	3,835,800	710,720	18.53%	194
Preaction Sprinkler for RHR Pump Rooms & Intake Station	147,000	27,200	18.50%	195
Install Four Jib Cranes	182,000	33,600	18.46%	196

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TABLE 5 (cont.)

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./QA COSTS	ENG./QA COSTS %	RANKING
Steam Generator Mock-Up	431,000	78,400	18.19%	197
Install Redundant Suppression Pool Monitoring System	1,453,000	260,800	17.95%	198
Reactor Head Area Cable Support Structure	4,499,000	806,400	17.92%	199
Full Flow Condensate Polishing Demineralizer (FFCPB)	90,000,000	16,000,000	17.78%	200
Install Moisture Seperator (MSR) Drain Demineralizer	1,012,000	179,200	17.71%	201
Scram Discharge Instrument Volume	1,050,000	184,000	17.52%	202
Replace Containment Vent Valves	4,125,000	720,000	17.45%	203
S & A Building Phase C	1,210,000	208,000	17.19%	204
Nuclear Department Office Building	23,600,000	4,000,000	16.95%	205
Construct a Radwaste Facility	1,987,000	329,600	16.59%	206
Component Cooling Water System Modification	3,020,000	496,000	16.42%	207
Volume Reduction System	12,490,000	2,040,000	16.33%	208
Radwaste System Phase A Modification	2,195,000	353,600	16.11%	209
Fuel Handling Extension	24,230,000	3,864,000	15.95%	210
Replace 125V/250V Station Batteries	955,000	152,000	15.92%	211
Testability of Sensor Systems	14,948,600	2,352,800	15.74%	212
Simulator (Replicate)	14,739,000	2,281,600	15.48%	213
Solenoid Valves	94,000	14,400	15.32%	214
Low-Level Radwaste Storage	2,665,000	400,000	15.01%	215
Recirculation Pipe Replacement	70,790,000	10,576,000	14.94%	216
Anticipated Transient Without Scram Modification	1,192,000	174,400	14.63%	217
Valve Position Switches	1,266,000	180,800	14.28%	218
Liquid and Dry Active Waste (DAW) Radwaste Processing	861,000	118,400	13.75%	219
Add 600V Load Centers	386,000	51,200	13.26%	220
Construct a Personnel/Shoe Facility	11,975,000	1,536,000	12.83%	221
Replace Cooling Tower Fill Support Columns	998,000	129,600	12.99%	222
Install Auxiliary Feed Pump Turbine Exhaust Lines	3,966,000	508,800	12.83%	223
Replace Reactor Coolant Pump Seals With New Design	3,781,000	480,000	12.70%	224
Residual Heat Removal (RHR) System Valves Replacement	3,070,000	384,000	12.51%	225
Dry Active Waste Facility	2,750,000	320,000	11.64%	226
RHR Throttle Valves	3,691,000	406,400	11.01%	227
Inverter/Vital A/C System	1,875,000	200,000	10.67%	228
Construction Office Renovation	1,531,000	160,000	10.45%	229
Nuclear Training Center	8,750,000	880,000	10.06%	230
Plant Referenced Simulator	9,171,000	916,800	10.00%	231
Training Facility Addition	2,448,000	243,200	9.93%	232
Extraction Steam Piping Replacement	13,929,000	1,347,200	9.67%	233
Turkey Point Steam Generator Replacement	167,975,000	16,040,000	9.55%	234
Steam Generator Chemical Cleaning	12,922,000	1,230,400	9.52%	235
Containment Model	505,000	44,800	8.87%	236
Air Dryers for Diesel Generators	454,000	38,400	8.46%	237
Hydrogen Recombiner Installation	3,203,000	262,400	8.19%	238
Fire Protection Penetration Seal Upgrade	19,262,000	1,550,400	8.05%	239
Install Safeguards Transfer Switches	541,000	43,200	7.99%	240
Replacement of Process Computer	1,544,000	120,000	7.77%	241
Waste Water System	3,720,000	288,000	7.74%	242
Induction Heating Stress Improvement	8,072,000	616,000	7.63%	243
Plant Process Computer System (PPCS)	4,976,000	345,600	6.95%	244
Records Storage Vault	175,000	12,000	6.86%	245

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TABLE 5 (cont.)

OTHER ELECTRIC UTILITIES COST DATA *
(AFUDC EXCLUDED)

TITLE	DIRECT COSTS	ENG./QA COSTS	ENG./QA COSTS %	RANKING
Neutron Monitoring System Component Replace	526,000	35,200	6.69%	246
Spent Fuel Reracking	3,656,000	244,800	6.70%	247
Fire Protection Yard Main	21,340,800	1,377,120	6.45%	248
Circulating and Essential Service Water System Pipe Replacement	1,620,000	96,000	5.93%	249
Design, Procure, and Replace All Non-Qual. Plant Elec. Equip.	8,632,000	507,200	5.88%	250
Warehouse/Office Facility Justification	4,038,000	235,200	5.82%	251
Waste Volume Reduction Facility	22,913,000	1,320,000	5.76%	252
Mobile Storage System	286,000	16,000	5.59%	253
Add 5th Vital Battery, Chargers, & Switching Circuitry	2,171,000	121,600	5.60%	254
Containment Fan Cooler Replacement	5,800,000	320,000	5.52%	255
Pipe Replacement	10,153,000	556,800	5.48%	256
Spent Fuel Modification	1,518,000	81,600	5.38%	257
Replace Copper Tubing in FW Heaters	4,920,000	264,000	5.37%	258
Condensate Demineralizer System	2,076,000	110,400	5.32%	259
Change Powerhouse ERCW Carbon Steel to Stainless	1,293,000	67,200	5.20%	260
Shoreline Erosion Protection	2,809,000	145,600	5.18%	261
Spent Fuel Pool Rerack	6,405,000	241,600	3.77%	262
Steam Generator Tube Sleeving	25,546,000	958,400	3.75%	263
Replace Containment Electrical Penetrations	4,072,000	152,000	3.73%	264
Construct Maintenance Staging Building	2,864,000	89,600	3.13%	265
Nuclear Training Center	29,800,000	800,000	2.68%	266
Intergranular Stress Corrosion	92,684,000	2,304,000	2.49%	267
Security Power Block and Watch Towers	8,701,000	214,400	2.46%	268
Inst. Extended Test Hydrogen Water Chemistry Sys.	1,675,000	40,000	2.39%	269
Secondary Side System Modification - Steam Gen. Preserv.	4,025,000	94,400	2.35%	270
Turbine Rotor Replacement	16,730,200	390,880	2.34%	271
Reactor Vessel Level Indicating System	4,146,000	94,400	2.28%	272
Waste Management Facility	1,252,600	27,840	2.22%	273
Reactor Vessel Pipe Restraints	2,002,000	43,200	2.16%	274
Add Oil Piping t actor Coolant Pump	88,000	1,600	1.82%	275
RTD'S Analysis	818,000	14,400	1.76%	276
New Emergency Operations Facility (EOF)	990,000	16,000	1.62%	277
Turbine Rotor Replacement	13,862,800	219,520	1.58%	278
Postaccident Sampling Facility (Design and Construct)	5,276,000	81,600	1.55%	279
Double Weld Recirculation Inspect (NINAC)	1,260,000	16,000	1.27%	280
Iodine Radiation Monitoring System	1,497,000	17,600	1.18%	281
		MEDIAN	27.86%	

* COST DATA PROVIDED BY NORTHEAST UTILITIES, AND BASED ON THEIR SURVEY OF OTHER ELECTRIC UTILITIES

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TABLE 6

SANDIA STUDY**

SHUTDOWN DECAY HEAT REMOVAL REQUIREMENTS
(NUREG-0606, USI A-45)
PROPOSED NEW CONSTRUCTION TYPE MODIFICATIONS

PLANT FACILITY	PLANT TYPE	MODS	H.O. ENGR./QA COST ($000's)	DIRECT COST ($000's)	ENGR./QA COST AS % OF DIRECT COST	ACCOUNTS* AFFECTED
1	PWR	3	6,203	21,390	29	S&I, RPE & EPE
2	PWR	3	8,213	28,321	29	S&I, RPE & EPE
3	BWR	1	1,858	6,567	28	S&I, RPE & EPE
		3	1,917	7,420	26	S&I, RPE & EPE
		5	8,958	30,891	29	S&I, RPE & EPE
4	PWR	4	6,490	23,172	28	S&I, RPE & EPE
5	BWR	1	2,458	10,264	24	S&I, RPE & EPE
		5	7,491	25,831	29	S&I, RPE & EPE
				MEDIAN =	29%	

* From EEDB-Phase VII Code-of-Accounts
S&I - Structures & Improvements
RPE - Reactor Plant Equipment
EPE - Electric Plant Equipment

** These data and associated cost factors are based upon cost data developed by United Engineers for Sandia, in support of their program to provide solutions to unresolved safety issue A45, "Decay Heat Removal."

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in estimating engineering/QA costs but the reader is cautioned that considerable judgment and expertise is necessary to extract meaningful results. At issue is the extreme variability of cost factors at this level of detail (cost factors at the 3 digit level of detail range from approximately 3% to over 800%). Given this level of variation, estimates derived from 3-digit costs have the potential to produce highly atypical results. An analyst must not only be able to identify the relevant 3-digit accounts but also must be confident that the specific repair is representative of the overall 3-digit activity in these accounts. Without these kinds of assurances a user should be discouraged from using this more detailed estimating approach.

It is noted from the various data sources that the data points vary over a broad range, which is not totally unexpected. However, there are cases where a very costly repair would require only a minimum amount of engineering. This would produce an extremely low engineering/QA cost factor. Alternatively, a very inexpensive repair could still require a de minimis level of engineering effort that percentage-wise would result in a very high engineering/QA cost factor. These examples are indicative of the desirability of factoring in case-specific knowledge whenever it is available.

To facilitate the utilization of engineering/QA cost factors, a recommended point estimate is provided for each work environment. A cost factor of 25 percent is adopted for modifications to existing structures/systems, and 30 percent for modifications performed in a new construction environment, as shown in Table 1. These are median values which are viewed as representative, based on the data results. These percentages are applicable where the proposed modifications entail moderate to extensive structure/system changes or additions.

5. General Approach

The results presented in Tables 1 and 1A, when multiplied by the direct cost of a structure/system change or addition, will generate a reasonable order-of-magnitude estimate of the engineering/QA costs associated with that physical modification. In general, this approach relies on the Energy Economic Data Base (EEDB) for baseline estimates for the direct cost of installing specific structures, systems, and pieces of equipment at a nuclear power plant.

The EEDB estimates reflect actual cost experience within a new construction environment. Consequently, for new construction requirements the EEDB direct cost, in an unencumbered form, can be multiplied by the appropriate engineering/QA cost factor, from Tables 1 and 1A, to obtain an estimate for engineering and QA activity.

For modifications performed on existing structures and systems, the EEDB baseline direct cost should be adjusted to allow for such things as working in a radiation environment, poor access, congestion and interference, etc. which typically occur on construction tasks at operating reactors and can occur under certain circumstances at reactors under construction. For guidance in performing such adjustments the reader is referred to NUREG/CR-4568, "A Handbook For Quick Cost Estimates: A Method for Developing Quick Approximate Estimates of Costs for Generic Actions for Nuclear Power Plants",

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and NUREG/CR-4627, "Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses". Once the EEDB estimate has been adjusted, it can be multiplied by the appropriate engineering/QA cost factor for operating plants, from Table 1, to obtain the engineering/QA cost applicable to a modification on an existing structure/system.

In summary, the following outlines the major steps which should be taken to effectively utilize the cost information contained in this report.

- o Identify specific construction/installation task(s) associated with NRC requirements;
- o Locate similar or comparable task(s) in EEDB and extract base line direct cost for equipment, materials, and labor;
- o For modifications in a new construction environment the engineering/QA cost is obtained by multiplying the EEDB direct cost by the appropriate engineering/QA cost factor from Tables 1 or 1A;
- o For modifications to existing structures/systems, the EEDB baseline direct cost is adjusted to account for differences in labor productivity, and rework requirements. Guidance in making such adjustments is available in NUREG/CR-4568, and NUREG/CR-4627. The adjusted EEDB is then multiplied by the appropriate engineering/QA cost factor for operating plants, from Table 1, to obtain the engineering/QA cost.
- o Sum results above over all impacted reactors to obtain total industry engineering/QA cost associated with installation/ construction effort.

There will occur instances where the EEDB is not applicable, and the analyst must work from a direct cost estimate supplied by a third party. In these instances, the basis for such direct cost estimates must be established and placed on a basis consistent with the nuclear work environments discussed in this report.

Other original direct cost estimates might be formulated using such sources as Richardson Engineering Estimating Standards and G.S. Means Construction Standards. Use of these familiar data bases will entail initial adjustment to place estimates on a nuclear construction basis. For instance, the Richardson system includes allowance for a number of incidental work tasks affecting productivity, such as coffee breaks, materials handling, tool adjustment, etc. These non-operational items range from 15 to 30 percent of a normal work day, and are far less than the non-productive time observed in nuclear projects. Thus, labor hours calculated by the Richardson system must be multiplied by a factor of about 2 in order to bring them into line with a nuclear new construction baseline of 60 percent non-productive time. Only at that point can new construction engineering/QA cost factors described here be applied. If the modification impacts existing structures/systems, a further adjustment to account for rework and additional productivity losses is required prior to applying the appropriate engineering/QA cost factor.

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6. Illustrative Example

The Technical Support Center (TSC) requirement, which is discussed in considerable detail in NUREG/CR-3971, is offered as an example to illustrate the application of the engineering/QA cost factors.

Although the TSC requirement impacts operating reactors, it involves structures and systems that are independent and separate from the operating plant. Consequently, cost factors applicable to new construction are appropriate.

Knowledge of the TSC requirement enables an analyst to extract the following direct costs from the EEDB. The direct costs for the TSC (rounded off) were obtained from Table 7, which consists of extracts from the EEDB VI, 1139 MWe Pressurized Water Reactor Cost Estimate.

TSC ACCOUNT NO.	DESCRIPTION	DIRECT COST ($)
218L	TSC Building Structure and Services	628,000
227.9	TSC Instrumentation	1,110,000*
243.15	TSC System Control Panels	323,000*
TOTAL		2,061,000

By multiplying the percentages shown in Table 1A by the above direct costs, the Engineering/QA costs for the TSC were developed as follows:

TSC ACCOUNT NO.	TSC DIRECT COST ($)	ENGR./QA PERCENT (TWO-DIGIT LEVEL)	ENGR./QA COST AT TWO-DIGIT LEVEL ($)
218L	628,000	37	232,000
227.9	1,110,000	33	366,000
243.15	323,000	28	90,000
TOTALS	2,061,000	33	688,000

The results show that the bottom line Engineering/QA cost as a percent of the direct cost, is 33%. This agrees reasonably well with the cost factors developed for new construction, as shown in Table 1.

7. Caveat

In conclusion, it is emphasized that caution should be exercised in using the data developed from this study. It is not advisable to regard the percentages and factors developed as "Cast in Concrete" and applicable to all cases. Their use should always be tempered with one's knowledge of the circumstances surrounding the specific modification in question. Further,

* Accounts 227.9 and 243.15 from Table 8 were adjusted to reflect only the TSC cost content.

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TABLE 7 - UE&C, INC. ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI,
1139 MWe PRESSURIZED WATER REACTOR

PLANT CODE 148 | COST BASIS 01/83 | UNITED ENGINEERS & CONSTRUCTORS INC. ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI 1139 MWE PRESSURIZED WATER REACTOR | PAGE 1 | 09/28/83

ACCT NO.	ACCOUNT DESCRIPTION	FACTORY QUANTITY	FACTORY COSTS	SITE QUANTITY	SITE LABOR HRS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
218L.	TECHNICAL SUPPORT CENTER							
218L.1	BUILDING STRUCTURE							
218L.11	EXCAVATION WORK							
218L.111	EARTH EXCAVATION							
218L.112	ROCK EXCAVATION							
218L.113	CONCRETE FILL							
218L.114	FILL + BACKFILL							
218L.115	DEWATERING							
	218L.11 EXCAVATION WORK							
218L.13	SUBSTRUCTURE CONCRETE							
218L.131	FORMWORK			500 SF	400 MH	7,297	1,500	
218L.132	REINFORCING STEEL			23 TN	920 MH	18,202	13,915	
218L.133	CONCRETE			250 CY	1050 MH	16,930	9,750	
218L.134	EMBEDDED STEEL							
218L.135	FLOOR FINISH			3308 SF	165 MH	2,666	198	
218L.136	WATERPROOFING							
218L.137	CONSTRUCTION JOINTS			230 SF	230 MH	4,196	426	
218L.138	RUBBING CONCRETE SURFACE							
218L.139	WIRE FABRIC			6620 SF	132 MH	2,620	1,456	
	218L.13 SUBSTRUCTURE CONCRETE				2897 MH	51,911	27,245	79,156

TABLE 7 (Cont'd)

PLANT CODE 148 | COST BASIS 01/83 | UNITED ENGINEERS & CONSTRUCTORS INC. | ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI | 1139 MWE PRESSURIZED WATER REACTOR | PAGE 2 | 09/28/83

ACCT NO.	ACCOUNT DESCRIPTION	FACTORY QUANTITY	FACTORY COSTS	SITE QUANTITY	SITE LABOR HRS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
218L.14	SUPERSTRUCTURE							
218L.141	CONCRETE WORK							
218L.1411	FORMWORK							
218L.14111	FORMWORK-WOOD			6468 SF	5821 MH	106,204	16,170	
218L.14112	FORMWORK-METAL			3308 SF	496 MH	9,839	9,924	
	218L.1411 FORMWORK				6317 MH	116,043	26,094	142,137
218L.1412	REINFORCING STEEL			31 TN	1705 MH	33,735	18,755	
218L.1413	CONCRETE			243 CY	1130 MH	18,219	9,477	
218L.1417	CONSTRUCTION JOINTS			500 SF	500 MH	9,122	925	
218L.1418	RUBBING CONCRETE SURFACES			3234 SF	582 MH	9,385	809	
	218L.141 CONCRETE WORK				10234 MH	186,504	56,060	242,564
218L.142	STRUCT. + MISC. STEEL			53 TN	2385 MH	47,292	75,260	
218L.143	EXTERIOR WALLS							
218L.144	ROOF DECK							
218L.145	ROOFING + FLASHING							
218L.1452	B.U.ROOF.+FLASH(NO INSUL.)			3300 SF	264 MH	5,166	5,610	
	218L.145 ROOFING + FLASHING				264 MH	5,166	5,610	10,776
218L.147	DOORS			180 SF	144 MH	2,794	3,800	
218L.148	WALL,FLOOR,+CEILING FINISH							
218L.1481	VINYL TILE FLOOR			3080 SF	246 MH	4,772	4,188	
218L.1482	SUSPENDED CEILING			3080 SF	308 MH	5,978	3,234	

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TABLE 7 (Cont'd)

PLANT CODE 148 | COST BASIS 01/83 | UNITED ENGINEERS & CONSTRUCTORS INC. ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI 1139 MWE PRESSURIZED WATER REACTOR | PAGE 3 | 09/28/83

ACCT NO.	ACCOUNT DESCRIPTION	FACTORY QUANTITY	FACTORY COSTS	SITE QUANTITY	SITE LABOR HRS.	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
218L.1483	SANDWICH PANELS			1600 SF	240 MH	4,686	14,389	
218L.1486	RAISED FLOOR(DISPLAY AREA)			1000 SF	450 MH	8,730	2,450	
	218L.148 WALL,FLOOR,+CEILING FINISH				1244 MH	24,133	24,231	48,364
218L.149	PAINTING							
218L.1491	CONCRETE			3000 SF	570 MH	8,556	630	
218L.1492	STEELWORK (PAINTING)			83 TN	392 MH	5,884	1,325	
218L.1493	METAL DECK			3300 SF	99 MH	1,486	528	
	218L.149 PAINTING				1081 MH	15,926	2,483	18,409
	218L.14 SUPERSTRUCTURE				15332 MH	281,813	167,244	449,059
	218L.1 BUILDING STRUCTURE				16229 MH	333,726	194,489	528,216
218L.2	BUILDING SERVICES	1 LT	60,000	1 LT	1500 MH	30,419	9,126	
218L.21	PLUMBING + DRAINS							
218L.22	HEATING,VENTILATION + AC							
218L.24	LIGHTING + SERVICE POWER							
	218L.2 BUILDING SERVICES		60,000		1500 MH	30,419	9,126	99,545
	218L. TECHNICAL SUPPORT CENTER		60,000		19729 MH	364,145	203,615	627,760
227.9	TMI INSTRUMENTATION	1 LT	2,160,060	1 LT	57900 MH	1,144,736	24,686	
242.18	TSC + OSC SYS CONTROL PNLS	1 LT	595,474	1 LT	1850 MH	36,521	12,943	

they are most applicable for those actions requiring only rough estimations or as a check on the reasonableness of cost estimates obtained from licensees or others. Where detailed cost estimation is required, these values should be viewed as a guide and as part of the process in addressing and quantifying this cost consideration.

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II. DATA COLLECTION

1. Utility Survey Data - Operating Plants

During the month of July 1985, United sent a questionnaire to twenty-six utilities with nuclear units under construction or with recently completed nuclear plants. The questionnaire was designed to obtain the total direct installation cost of the modification and the indirect Engineering/Quality Control cost as a percentage of the direct modification cost. Check lists indicated which major systems and structures were affected along with indications of radiation environment, seismic category, safety class and whether the change was done by the owners, A/E or vendor. The transmittal letter, instruction sheet and questionnaire are included as an appendix.

The list of utilities that were contacted are as follows:

Tennessee Valley Authority
Niagara Mohawk Power Corporation
Public Service Electric & Gas Co.
Northeast Utilities
Duquesne Light Company
Duke Power Company
Louisiana Power & Light Company
Public Service New Hampshire
Georgia Power Company
Cleveland Electric Illuminating Co.
South Carolina Electric & Gas Co.
Mississippi Power & Light Company
Arizona Public Service Company
Kansas Gas and Electric Company
Gulf States Utilities Company
Houston Lighting and Power Company
Union Electric Company
Detroit Edison Company
Pacific Gas & Electric Company
Philadelphia Electric Company
Illinois Power Company
Carolina Power & Light Company
Texas Utilities Generating Company
Washington Public Power Supply System
Commonwealth Edison Company
Florida Power & Light Company

During late August telephone follow-ups were conducted to encourage the utilities to participate in the survey and resolve any questions utility management might have concerning the questionnaire. Managers and engineers of the utility industry agreed that what was being studied was worthwhile and they would participate if possible.

It became apparent that data for modifications to units under construction were not available. Capital budgets are established on a yearly basis for utility construction projects and modifications are incorporated within the budget. Separate accounts are not set up by modification, therefore data are lost within the annual capital budget allocation. With this realization, United requested that the utilities provide data for their operating plants. Many agreed to attempt to assemble data for this effort.

The utility response in supplying data that could be analyzed was extremely slow. The first response did not arrive until September 11, 1985.

United attempted to approach the Electric Utility Cost Group (EUCG) through a member utility to determine if the EUCG would be willing to share information with regard to modifications of nuclear stations. The request was put to a vote at the EUCG meeting during the early

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summer (June 1985) and the majority voted against sharing data. Instead of pursuing the group any further, about ten individuals were contacted separately to determine if there was a willingness to share data. A number were willing to share, but to date, no one has supplied any data from the EUCG which is useful.

Data were received from two utilities for three different operating plants. Information was provided on the questionnaire and brief conversations with utility representatives quickly confirmed the data. Two other utilities supplied data but did not use the questionnaire provided. These data were unuseable due to lack of definiton and content. The current information sample from the survey reflect fifteen data points involving structures, nuclear/mechanical systems, electrical systems and instrumentation and control systems.

The NRC has been made aware of the slow response of Utilities to the questionnaire for data.

2. Sandia Study - Operating Plants and New Construction

United under contract to Sandia, performed a study to provide possible design solutions to satisfy unresolved safety issue A45 from NUREG-0606. The range of design solutions extend from simple off the shelf component additions to a complete add-on decay heat removal system. The various design modifications to five operating plants provide additional data points for this study.

3. Other Electric Utilities Data - Operating Plants

At the request of the NRC, United contacted Northeast Utilities to obtain additional modification cost data for other electric utilities. The cost data provided by Northeast Utilities are based on their survey of other electric utilities, and constitute the largest collection of modifications.

4. Northeast Utilities Data - Operating Plants

United also requested Northeast Utilities to provide modification cost data, based on their own operating nuclear plant experience. United received this data on December 23, 1986 for three of their plants.

5. EEDB-Phase VII - New Construction

The EEDB-Phase VII was analyzed to determine the engineering content associated with individual two and three-digit accounts in the capital investment costs. The distribution of home office engineering and quality control is discussed later in this report.

6. NUREG/CR-3971 - New Construction

In the Handbook for Cost Estimating published in October 1984 the Technical Support Center required by the TMI accident was presented as an example problem to exercise the methodology. An analysis of the problem provides an additional data point for Engineering/QA as a function of the direct cost.

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APPENDIX TO SECTION II

UTILITY SURVEY QUESTIONNAIRE

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QUESTIONNAIRE COVER LETTER

July 29, 1985

NRC COST ESTIMATING FACTORS

United Engineers has been contracted by the Nuclear Regulatory Commission (NRC) to perform analyses in order to develop cost factor* estimates for both engineering and quality control efforts associated with modifications to nuclear power plants. The NRC's intended purpose is to use the cost factor estimates as part of their evaluative technique in performing cost benefit analyses of proposed regulatory actions. Valid cost factor estimates based on actual experience of utilities and A-E's will be more beneficial to the industry than some invention by a technical analyst, since it will provide a real world basis for evaluation purposes. We, therefore, believe it is in the best interest of the industry to provide such data.

We are requesting your participation in providing information on several examples of modifications to your nuclear power plant in order for United to assemble cost factors for engineering and quality control. The questionnaire is designed to be easily answered and collated by having a high degree of aggregation yet being informationally complete. The specific NRC bulletin and modification are indicated on each data sheet required. We are interested in specific modifications to your and other utilities' plants in the areas of:

- Post Accident Sampling System
- Reactor Vessel Head Vent
- Fire Protection
- Emergency Planning
- Environmental Qualifications
- Security
- Combustible Gas Control
- Spent Fuel Pool Expansions
- Low Level Waste Facilities
- Containment Isolation
- Service Water Piping Replacements

*Cost Factor for Engineering = Engineering Cost/Direct Installed Cost

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July 29, 1985

You should answer Sections II - IV of the questionnaire for each modification you are responding to. We are interested in the following locations (defined in questionnaire checklist):

- Structures & Improvements
- Reactor Plant Equipment
- Turbine Plant Equipment
- Miscellaneous Plant Equipment
- Main Condenser Cooling System

It would be helpful if the modifications vary in their costs, and in their application to radiation environments, seismicly qualified structures and safety class. If modifications have been performed on your plant in the past three years, please provide examples of these in the area of piping and electrical modifications that you deem significant. Blank questionnaires are provided.

Your participation is vital for the analyses being conducted in order for the NRC's analysts to perform valid Cost/Benefit evaluations.

We will be contacting you by telephone a few days after you have had a chance to review the questionnaire to discuss any question or concerns you might have about your participation in this endeavor.

Very truly yours,

E. J. Ziegler
Consulting Engineer

EJZ:ss
Enclosures

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INSTRUCTIONS FOR COST FACTOR QUESTIONNAIRE

The questionnaire is divided into four main sections. Section I is general plant information, and needs to be filled out only once. Each modification should be answered on a separate questionnaire. These instructions refer to each question by the corresponding letter on the questionnaire and explains in detail how they should be answered:

SECTION I: PLANT INFORMATION

- This section includes background information on your facility. Please check for it's accuracy.

SECTION II: MODIFICATION SPECIFICATIONS

A. Indicate the modification and the documents which invoked it.

B. Provide month and year when modification was begun and finished (or is estimated to be finished).

C. Cost: Check the category which approximates the installed cost of modification (this excludes engineering and quality control; i.e. if installed cost was $150,000 check the second category).

D. Location: Check the major location for where the modification was performed. Section IV provides a list for what is included in these categories.

E,F,G: Was the modification performed:

E. On a seismic category I structure?
F. On safety class equipment?
G. In a radiation environment?

H. Engineering: Identify the major supplier of engineering service.

I. Quality Control: Identify the major supplier of quality control.

SECTION III: COST FACTORS

The cost factors of the modifications are defined as follows:

A. Engineering Cost Factor = $\frac{\text{Engineering Cost}}{\text{Direct Installed Cost}}$ where Engineering is defined as:

Includes AE or utility home office engineering and design, procurement, expediting, estimating, cost control, engineering, planning, scheduling, reproduction services and expenses associated with performance of these services. Salaries, overheads and fees should be included.

B. Quality Control = $\frac{\text{Quality Control Cost}}{\text{Direct Installed Cost}}$ where Quality Control is defined as

Services include reviews, audits, vendor surveillance, etcetera as required for design and construction. Salaries, overheads and fees should be included.

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SECTION III: COST FACTORS (cont'd)

If it is not possible for you to separate the engineering and quality control costs you may provide one combined cost factor Question C. Question D asks for the total installed cost (which excludes engineering and quality control costs) and is optional.

SECTION IV: LOCATION CHECKLIST

This section provides you the opportunity to indicate in more detail about the location and costs included in the cost factor. For the location checked in Section II.D, please indicate the major structures and systems which were included (I) and excluded (E) from the modification. These major accounts contain Factory Equipment, Site Labor and Site Material.

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COST FACTOR QUESTIONNAIRE

NUCLEAR POWER PLANT MODIFICATION COSTS

SECTION I: PLANT INFORMATION

FACILITY: _____ DATE COMMERCIAL OPERATE: _____

LOCATION: _____ CONDENSER COOLING METHOD: _____

TYPE OF REACTOR: _____ NUCLEAR STEAM SYSTEM SUPPLIER: _____

DATE OF INITIAL CRITICALITY: _____ TURBINE SUPPLIER: _____

SECTION II: MODIFICATION SPECIFICATIONS

A. MODIFICATION PERFORMED UNDER NRC ORDER: _____

B. TIME PERIOD: BEGUN _____ FINISHED _____

C. INSTALLED COST ($1,000's)

- ☐ < $100
- ☐ $100 - 500
- ☐ $500 - 1,000
- ☐ > $1,000

D. LOCATION

- ☐ Structures & Improvements
- ☐ Reactor Plant Equipment
- ☐ Turbine Plant Equipment
- ☐ Misc. Plant Equipment
- ☐ Main Cond. Cooling System

E. SEISMIC CATEGORY

- ☐ Seismic Cat. 1
- ☐ Non-Seismic Cat. 1

F. SAFETY CLASS

- ☐ Safety
- ☐ Non-Safety

G. ENVIRONMENT

- ☐ Radioactive
- ☐ Non-radioactive

H. ENGINEERING

- ☐ Arch/Engineer
- ☐ Utility
- ☐ Vendor

I. QUALITY CONTROL

- ☐ Arch/Engineer
- ☐ Utility
- ☐ Vendor

SECTION III: MODIFICATION COST FACTORS

A. ENGINEERING COST FACTOR (%) = _____

B. QUALITY CONTROL COST FACTOR (%) = _____

C. COMBINED ENGINEERING & QUALITY CONTROL COST FACTOR (%) = _____
(If A & B Not Available)

D. TOTAL INSTALLED COST (OPTIONAL) = _____
(Excludes Engineering and Quality Control)

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SECTION IV: LOCATION CHECKLIST

The major accounts contain Factory Equipment, Site Labor and Site Material. Please indicate your inclusion (I) and exclusions (E) for the following major structures and systems:

A. STRUCTURES AND IMPROVEMENTS

I	E		I	E	
☐	☐	Buildings	☐	☐	Railroads
☐	☐	Structures	☐	☐	Rack Facilities
☐	☐	Foundations	☐	☐	Heating
☐	☐	Tunnels	☐	☐	Ventilating
☐	☐	Excavation	☐	☐	Air Conditioning
☐	☐	Dewatering	☐	☐	Lighting
☐	☐	Grading	☐	☐	Service Power & Structures
☐	☐	Roadways			

B. REACTOR PLANT EQUIPMENT

I	E		I	E	
☐	☐	Nuclear Steam Supply System	☐	☐	Fuel Storage, Cleaning & Inspection
☐	☐	Reactor Equipment	☐	☐	Inert Gas System
☐	☐	Reactor Coolant System	☐	☐	Reactor Makeup Water System
☐	☐	Residual Heat Removal System	☐	☐	Chemical & Volume Control System
☐	☐	Safety Injection System	☐	☐	Fluid Leak Detection System
☐	☐	Containment Spray System	☐	☐	Nuclear Service Water
☐	☐	Combustible Gas Control System	☐	☐	Maintenance Equipment
☐	☐	Liquid Radwaste	☐	☐	Instrumentation & Control
☐	☐	Solid Radwaste	☐	☐	Process Computer
☐	☐	Gaseous Radwaste	☐	☐	Monitoring System
☐	☐	Fuel Handling Tools & Equipment			

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C. TURBINE PLANT EQUIPMENT

I	E		I	E	
☐	☐	Turbine Generator	☐	☐	Instrumentation & Control
☐	☐	Condenser	☐	☐	Turbine Bypass System
☐	☐	Condensate System	☐	☐	Extraction Steam System
☐	☐	Feedwater System	☐	☐	Main Steam System
☐	☐	T. G. Support	☐	☐	Closed Cooling Water System
☐	☐	Main Vapor Piping System	☐	☐	Chemical Treatment System
☐	☐	Auxiliary Support System	☐	☐	Neutralization System

D. ELECTRIC PLANT EQUIPMENT

I	E		I	E	
☐	☐	Switchgear	☐	☐	Lightening Protection
☐	☐	Station Service Equipment	☐	☐	Cathodic Protection
☐	☐	Swithcboard	☐	☐	Underground Dust Runs
☐	☐	Control Panels	☐	☐	Cable Tray
☐	☐	Aux. Power & Signal Board	☐	☐	Conduit
☐	☐	General Station Ground System	☐	☐	Power & Control Wiring
☐	☐	Fire Detection			

E. MISCELLANEOUS

I	E		I	E	
☐	☐	Cranes & Hoister	☐	☐	Furnishings
☐	☐	Air, Water & Steam Service System	☐	☐	Fixtures
☐	☐	Communications	☐	☐	Waste Water Treatment

F. MAIN CONDENSER HEAT REJECTION SYSTEM

I	E		I	E	
☐	☐	Makeup Water Intake	☐	☐	Cooling Tower Switchtear Bldg.
☐	☐	Circulating Water Pump House	☐	☐	Heat Rejection System
☐	☐	Makeup Water Pretreatment Bldg.			

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III. CATEGORIZATIONS OF PLANT STATUS FOR MODIFICATIONS

Engineering/QA cost as a percentage of the direct cost of a modification is dependent upon the construction or operating status of the power plant. Definitions about the construction and operating status of nuclear power plants provide the guide in selecting which cost factors are to be selected for a specific modification. The plant categories include new construction, operating plants and new construction at operating plants.

1. Category Descriptions

New Construction - Modifications are easily implemented since plants are not complete. Modifications are incorporated into the design, and implementation requires no tear outs or changes to existing structures and systems. This type of change is essentially part of the design process, therefore, the cost tends to be lower and engineering/QA cost as a percentage of the direct cost is higher. The data representing new construction were obtained from the Energy Economic Data Base VII.

Operating Plants - Modifications are difficult to implement in plants which are either nearing commercial operation or already operating. The difficulty of implementation results from congested areas, radiation and the shielding and safety concerns associated with exposure, and the problems of security. The combination of these factors has a direct effect on the productivity of craft labor and tends to make the overall cost of the modification higher than new construction. Since the cost of a change can be many times higher than the cost of new construction, the engineering cost is a lower percentage of direct cost. The data representing operating units were obtained from the following sources:

- United's survey of electric utilities through a questionnaire developed for the purpose.
- United's study, under contract to Sandia, to provide possible design solutions to satisfy unresolved safety issue A45 from NUREG-0606.
- Northeast Utilities' survey of other electric utilities.
- Northeast Utilities' review of their own nuclear plant experience.

New Construction At Operating Plants - Modifications of structures/systems that are independent and separate from the operating plant can be construed as new construction type modifications. The data representing this category were obtained from the TSC example of NUREG/CR-3971 and the Sandia study, where the facilities constructed were construed as independent structures.

For these type modifications, the home office engineering effort has a field counterpart of the same magnitude. This is similar to that for construction of future plants represented by a plant less than

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70% complete. However, there will be instances of new construction at operating plants where home office engineering represents most of the total engineering effort of modifications. In these cases, the analyst will need much more detailed knowledge of the modifications to be performed.

2. Types of Modifications

Structure/System modifications are physical changes to the station resulting from a requirement imposed on the owner. In contrast to this type of change is the requirement which does not cause a physical change but requires engineering analysis and quality assurance. An analytic modification has the potential to be completely engineering in nature, with little or no physical change to the plant. To estimate the effect of this type of change the analyst is directed to the procedures in NUREG/CR-3971.

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IV. DISCUSSION OF DATA

Six sources of information provided the data which United analyzed to establish the ranges of Engineering/QA content associated with modifications to nuclear power plants. Each data source is discussed with an example of the applicability of the data to a particular type of modification. The analyst is encouraged to follow the procedures outlined for quick cost estimates and to understand the categories defined in the previous section of this report.

1. Utility Survey Data - Operating Plants

   The questionnaires which were forwarded to utilities yielded fifteen useable data points for a variety of modifications to nuclear power plants. These data are presented in Table 2 and show that for operating plants, when system/structure type modifications are made, the median value for the Engineering/QA cost factor is 15%.

2. Sandia Study - Operating Plants and New Construction

   Sandia National Laboratories is the NRC's lead laboratory for developing solutions to unresolved safety issue A-45 "Decay Heat Removal." United Engineers, under contract to Sandia, performed a study to develop plant modifications, designs and cost estimates, in support of this effort. Sandia screened all U.S. plants and selected five plants for further evaluation. This evaluation consisted of designing plant modifications which, in various combinations, would bring each plant to the same evaluated core melt frequency. The proposed modifications ranged from the very simple, such as adding a test switch to a safety circuit or guy wires to a vent stack, to the very complex, such as building an "add-on" decay heat removal system with dedicated buildings, water supplies and power sources, and tieing it into the plant.

   For each modification proposed United performed the following activities:

   - Using available plant drawings, developed a preliminary approach to implementing the modification. Practicality/feasibility questions were discussed with Sandia, sometimes resulting in improvements to or alternate modifications.

   - Based on agreed upon approaches, prepared a plan for a site visit. The site visit was to confirm practicality/feasibility of the selected approach and to gather physical data (radiation levels, accessability, health restrictions, congestion, etc.) which determine the degree of difficulty in physically implementing the modification.

   - Conducted the site visit with two engineers in the most relevant disciplines and a cost engineer. Data was recorded using polaroid photographs and a dictating machine for the modification "walkdowns". The modifications were also discussed with the appropriate plant staff and additional drawings obtained as needed.

   - Completed the design and documented design criteria, design description, bill of materials and schedules in a modification design report.

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- o Developed a cost estimate based on methodology, which accounted for general experience on modification type jobs and the degree of difficulty associated with each modification.

- o Issued an integrated report covering all proposed modifications for each plant.

Eight modifications, involving the addition of systems and structures that are independent of the operating plant and are construed as new construction, were developed. These modifications, and the associated Engineering/QA costs as percentages of the direct costs, are presented in Table 6. The median value of these Engineering/QA factors is 29%.

Complimenting this data are eleven modifications developed for existing systems/structures of the operating plants. These modifications and the Engineering/QA costs, as percentages of the direct costs, are presented in Table 3. The median value of these Engineering/QA factors is 9%.

3. Other Electric Utilities Data - Operating Plants

At the request of the NRC, United contacted Northeast Utilities to obtain operating plant modification cost data for other electric utilities. The data provided by Northeast Utilities were based on their survey of other electric utilities. Cost data and Engineering/QA percents for 315 modifications, performed at various operating nuclear plants throughout the country, were included. This data source far exceeds the other five sources, in terms of the number of modifications included. It was necessary for United to adjust these data to put them on a consistent cost basis with the other data sources. This consisted of adding overhead to the engineering costs, and excluding modifications that resulted in unusually high and low Engineering/QA cost factors. All Engineering/QA factors over 200% and under 1% were excluded, resulting in a reduction in the total modifications from this source to 281, as shown in Table 5.

4. Northeast Utilities Data - Operating Plants

United also requested Northeast Utilities to provide modification cost data, based on their own operating nuclear plant experience. Cost data and Engineering/QA cost factors for 31 modifications, performed at three of their operating nuclear plants, were provided, as shown in Table 4.

5. EEDB-Phase VII - New Construction

The EEDB-VII provides the analyst with data for new construction of a nuclear power plant. United has analyzed the data, which shows that the Engineering/QA cost is approximately 30 percent of the total direct cost. The Engineering/QA cost (Account 92) was distributed among the direct code-of-accounts, at the two and three digit levels, and Engineering/QA cost factors developed at this level are presented in Table 8. The procedure for doing this is described below:

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TABLE 8

DISTRIBUTION OF HOME OFFICE & FIELD OFFICE ENGINEERING & SERVICE COSTS

AMONG THE DIRECT TWO AND THREE-DIGIT ACCOUNTS FOR THE PWR-HI MODEL

OF GEDB - PHASE VII

Acct. No.	Description	92 ACCOUNT % of H.O. Total	92 ACCOUNT Cost Dist. 10000	98 ACCOUNT Dist. Factor	98 ACCOUNT % of F.O. Total	98 ACCOUNT Cost Dist. 10000	92 + 98 ACCOUNTS % of H.O.+F.O. Total	92 + 98 ACCOUNTS Cost Dist. 10000	TOTAL DIRECT COST 10000 (1)	H.O. ENGR AS A % OF DIRECT COST
211	Yardwork	2.11%	7,230	14,000	3.30%	13,124	2.84%	20,354	32,904	21.97%
212	Reactor Containment Bldg	9.63%	33,006	30,335	12.86%	48,207	11.30%	81,243	104,167	31.71%
213	Turbine Room & Heater Bay	3.21%	11,260	15,961	3.91%	14,647	3.62%	26,007	30,362	29.61%
214	Security Building	0.18%	627	906	0.23%	850	0.21%	1,477	1,872	30.49%
215	Primary Aux Bldg + Tunnels	6.57%	22,330	17,969	6.49%	16,489	5.49%	39,019	27,424	80.13%
216	Waste Process Building	3.84%	13,167	13,700	3.37%	12,645	3.66%	25,812	23,330	34.37%
217	Fuel Storage Building	1.28%	4,107	5,416	1.33%	4,970	1.26%	9,077	11,067	34.61%
218A	Control Bu/D-G Building	3.06%	10,494	16,125	3.9[illegible]%	14,796	3.52%	25,290	31,457	33.32%
218B	Administration/Service Bldg.	0.61%	2,100	4,216	[illegible]%	3,669	0.88%	5,772	10,022	29.90%
218D	Fire Pump Hse incl Found	0.22%	771	457	0.11%	419	0.17%	1,190	539	143.14%
218E	Emergency Feed Pump Bldg	0.94%	1,161	2,099	0.50%	1,071	0.48%	3,032	3,042	30.04%
218F	Runway (ECA) Tunnels	0.12%	413	740	0.18%	679	0.15%	1,092	1,252	30.54%
218G	Electric Tunnels	0.29%	692	263	0.06%	241	0.13%	933	85	814.69%
218H	Non-Essential Supp Bldg	0.16%	541	453	0.11%	416	0.13%	957	705	68.93%
218J	Hbio Steam/FW Pipe Enc.	1.00%	3,347	4,464	1.30%	3,931	1.32%	9,470	12,627	30.09%
218K	Pipe Tunnels	0.07%	220	301	0.07%	276	0.07%	504	509	44.02%
218L	Technical Support Center	0.01%	31	241	0.08%	213	0.05%	264	879	5.00%
218P	Contain Eq Hatch Main Shield	0.17%	571	214	0.08%	208	0.12%	839	273	209.30%
218S	Waste water Treatment Bldg.	0.13%	407	312	0.13%	470	0.13%	907	934	46.00%
218T	Ultimate Heat Sink Str	0.56%	1,907	4,518	1.11%	4,146	0.85%	6,073	9,062	21.27%
218V	Const Ac Energ Air Intk Str	0.01%	49	68	0.02%	62	0.02%	111	119	91.27%
21	STRUCTURES & IMPROVEMENTS	33.50%	115,082	137,700	39.60%	144,799	36.18%	259,741	312,459	36.02%
220A	Nuclear Steam Supply (NSSS)	5.32%	18,256	6,005	1.49%	5,304	3.82%	23,040	164,000	11.13%
221	Reactor Equipment	0.61%	2,050	2,356	0.20%	3,000	0.71%	5,130	11,369	18.00%
222	Main Heat Xfr Xprt Sys	3.00%	13,040	13,735	3.37%	12,622	3.57%	25,662	29,931	42.23%
223	Safeguards System	4.72%	16,102	14,395	3.52%	13,210	4.09%	29,392	24,900	64.99%
224	Radwaste Processing	3.96%	13,304	11,346	2.70%	10,411	3.34%	23,995	24,451	55.11%
225	Fuel Handling/Storage	0.60%	2,049	1,053	0.43%	1,700	0.53%	3,749	4,390	47.13%
226	Other Reactor Plant Equip	11.07%	40,704	37,514	9.10%	34,424	10.47%	75,148	47,712	68.14%
227	NI Instr & Control	2.99%	10,240	8,457	2.12%	7,944	2.53%	18,192	22,620	45.29%
228	Reactor Plant Misc Items	0.10%	253	3,609	0.90%	3,385	0.52%	3,720	9,429	3.74%
22	REACTOR PLANT EQUIP	33.96%	116,306	100,451	24.63%	92,360	29.09%	208,866	350,010	33.29%

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TABLE 8 (Cont'd)

DISTRIBUTION OF HOME OFFICE & FIELD OFFICE ENGINEERING & SERVICE COSTS AMONG THE DIRECT TWO AND THREE-DIGIT ACCOUNTS FOR THE PWR-HE MODEL OF EEDB - PHASE VII

Acct. No.	Description	92 ACCOUNT % of H.O. Total	92 ACCOUNT Cost Dist. 10000	93 ACCOUNT Dist. Factor	93 ACCOUNT % of F.O. Total	93 ACCOUNT Cost Dist. 10000	92 + 93 ACCOUNTS % of H.O.+F.O. Total	92 + 93 ACCOUNTS Cost Dist. 10000	TOTAL DIRECT COST 10000 (1)	H.O. ENGR AS A % OF DIRECT COST
231	Turbine Generator	4.89%	16,338	11,997	2.94%	11,009	3.84%	27,347	125,343	13.19%
233	Condensing System	1.49%	5,115	10,432	2.55%	9,572	2.05%	14,687	33,183	15.41%
234	Feed Heating System	2.81%	9,432	11,819	2.89%	10,845	2.05%	20,477	32,106	30.00%
235	Other Turbine Plant Equip	3.43%	11,771	17,031	4.36%	16,362	3.92%	28,133	38,980	30.25%
236	Instrumentation & Control	1.28%	4,392	4,666	1.14%	4,282	1.21%	8,674	7,811	56.23%
237	Turbine Plant Misc Items	0.11%	381	3,752	0.92%	3,443	0.53%	3,824	9,774	3.90%
23	TURBINE PLANT EQUIP	13.95%	47,849	60,496	14.81%	55,513	14.00%	103,362	247,326	19.25%
241	Switchgear	0.58%	1,978	1,027	0.25%	942	0.41%	2,920	10,757	18.39%
242	Station Service Equipment	1.61%	5,540	3,645	0.89%	3,344	1.24%	8,884	19,941	27.70%
243	Switchboards	0.36%	1,227	636	0.16%	584	0.25%	1,811	1,927	63.66%
244	Protective Equip	0.87%	2,979	2,832	0.69%	2,599	0.78%	5,578	4,063	61.25%
245	Elect Struc & Wiring Contar	3.16%	10,845	23,442	5.74%	21,511	4.51%	32,356	40,107	27.04%
246	Power and Control Wiring	2.43%	8,326	13,051	3.68%	13,811	3.08%	22,137	33,071	25.18%
24	ELECTRIC PLANT EQUIP	9.01%	30,895	46,633	11.41%	42,792	10.26%	73,687	110,667	27.92%
251	Transportation & Lift Equip	0.15%	520	1,035	0.25%	949	0.21%	1,477	5,004	10.55%
252	Air, Water & Steam Svc Sys	5.70%	19,544	22,634	5.54%	20,770	5.62%	40,314	41,319	47.30%
253	Communications Equip	0.49%	1,671	3,234	0.79%	2,967	0.65%	4,638	7,229	23.11%
254	Furnishings & Fixtures	0.26%	891	652	0.16%	599	0.21%	1,490	2,775	32.11%
255	Waste Water Trtmt Equip	0.06%	193	1,307	0.32%	1,199	0.19%	1,392	3,058	6.31%
25	MISC PLANT EQUIP	6.65%	22,827	28,862	7.06%	26,484	6.87%	49,311	59,386	30.44%
261	Nt Rej Sys Structures	1.22%	4,172	3,307	0.81%	3,034	1.00%	7,206	5,130	81.32%
262	Nt Rej Sys Mech Equip	1.68%	5,762	10,923	2.67%	10,023	2.20%	15,785	40,627	11.85%
26	MAIN COND HT REJ SYSTEM	2.90%	9,934	14,229	3.48%	13,057	3.20%	22,991	53,757	18.48%
2	TOTAL DIRECT COST	100.00%	343,043	408,571	100.00%	374,915	100 00%	717,958	1,133,605	30 26%

TABLE 8 (Cont'd)

DISTRIBUTION OF HOME OFFICE & FIELD OFFICE ENGINEERING & SERVICE COSTS

AMONG THE DIRECT TWO AND THREE-DIGIT ACCOUNTS FOR THE PWR-HE MODEL

OF EEDB - PHASE VII

Acct No.	Description	92 ACCOUNT % of H.O. Total	92 ACCOUNT Cost Dist. 10000	98 ACCOUNT Sept. Factor	98 ACCOUNT % of F.O. Total	98 ACCOUNT Cost Dist. 10000	92 + 98 ACCOUNTS % of H.O.+F.O. Total	92 + 98 ACCOUNTS Cost Dist. 10000	TOTAL DIRECT COST 10000 (1)	H.O. ENGR AS A % OF DIRECT COST
	TWO-DIGIT SUMMARY									
21	STRUCTURES & IMPROVEMENTS	33.33%	115,032	137,709	30.68%	144,709	36.18%	259,741	312,459	36.02%
22	REACTOR PLANT EQUIP	33.96%	116,306	100,651	24.63%	92,360	29.09%	208,866	350,010	33.29%
23	TURBINE PLANT EQUIP	13.93%	47,849	60,496	14.81%	55,513	14.40%	103,362	247,326	19.33%
24	ELECTRIC PLANT EQUIP	9.01%	30,895	46,638	11.41%	42,792	10.26%	73,687	110,667	27.92%
25	MISC PLANT EQUIP	6.65%	22,827	20,062	7.06%	26,484	6.87%	49,311	59,386	38.44%
26	MAIN COND HT REJ SYSTEM	2.90%	9,934	14,229	3.48%	13,057	3.20%	22,991	33,737	18.48%
2	TOTAL MODEL COST	100.00%	343,048	400,571	100.00%	374,915	100.00%	717,958	1,133,685	30.26%

(1) INCLUDES TOTAL DIRECT COSTS PLUS PAYROLL INSURANCE AND TAXES FROM ACCOUNT 913, THAT ARE RELATED TO DIRECT CRAFT MANHOURS (678,009,000)

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HOME OFFICE AND FIELD OFFICE ENGINEERING AND SERVICE DEFINITIONS AND COST DISTRIBUTIONS

DEFINITIONS

Home Office Engineering and Services (Account 92) consists of three major subaccounts, which are defined as follows:

Home Office Services (Account 921)

These services include home office engineering and design, procurement and expediting activities, estimating and cost control, engineering planning and scheduling, home office reproduction services and expenses associated with performance of the above functions (i.e., telephone, postage, computer use, travel, etc.). The costs for these services include salaries of personnel, direct payroll-related costs (DPC), overhead loading expenses and fees for these services.

Home Office Quality Assurance (Accont 922)

This account includes the services of home office quality assurance engineers and staff personnel engaged in work on the project. Services include reviews, audits, vendor surveillance, etc. as required for design and construction of the nuclear safety-related portion of the facility. Costs for these services include salaries, DPC, overhead loading and expenses (i.e., travel) of these individuals.

Home Office Construction Management (Account 923)

These services include those of the construction manager and his assistants. Services of construction planning and scheduling, construction methods, labor relations, safety and security personnel are utilized as required. Costs for these services include salaries, DPC, overhead loading, and expenses.

Field Office Engineering and Services (Account 93) contains four major subaccounts:

Field Office Expenses (Account 931)

These expenses include costs associated with purchase and/or rental of furniture and equipment (including reproduction), communication charges, postage, stationery, other office supplies, first aid and medical expenses.

Field Job Supervision (Account 932)

This management function includes the resident construction superintendent and his assistants, craft labor supervisors, field accounting, payroll and administrative personnel, field construction schedulers, field purchasing personnel, warehousemen, survey parties, stenographers and clerical personnel. Costs of these services include salaries, DPC, overhead loading, relocation costs of key personnel, and fees.

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Field Quality Assurance/Quality Control (Account 933)

These services include those of personnel located at the job site engaged in equipment inspection, required documentation of safety-related equipment (nuclear power plants only) and inspection of construction activities. Costs included are salaries, DPC, and overhead loading.

Test and Startup Engineering (Account 934)

These services are associated with preparation of startup and plant operation manuals and test procedures, direction and supervision of testing of equipment and systems as the plant nears completion and direct of startup of the facility. Costs of these services include salaries, DPC, overhead loading, and miscellaneous related expenses. Costs of any craft labor required for startup and testing activities are included in the appropriate Direct Cost line items.

COST DISTRIBUTION

Home Office and Field Office Engineering and Service (HOE and FOE respectively) are indirect costs in a uniform code-of-accounts in UE&C's/DOE's Energy Economic Data Base (EEDB). Table 9 is a cost breakdown, at the two-digit level, of the EEDB-Phase VII, 1139 MWe PWR model. HOE is identified as account 92, and consists of costs associated with HOE engineering and design, procurement and expediting, estimating and cost control, planning and scheduling, reproduction services, clerical and administrative activities and related expenses. FOE is identified as account 93, and consists of costs associated with FOE construction management and assistants, craft labor supervision, quality assurance activities, test and startup engineering, accounting, purchasing, construction scheduling, clerical and administrative activities and related expenses.

The indirect HOE and FOE activities are related to the direct costs of the uniform code-of-accounts (i.e. Accounts 21 through 26). The distribution of the HOE and FOE account costs and manhours among the direct accounts at the three-digit system level, of the EEDB-Phase VII, 1139 MWe PWR model is accomplished as follows:

1. Home Office Engineering & Service (Account 92)

   a. Utilize UE&C's Design Task System (DTS), where designers assign their hours worked to various task categories, to quantify the designer hours required for a major nuclear plant project.

   b. Review the DTS data and assign designer hours to each three-digit account by job discipline, i.e. Electrical, Structural, Mechanical Piping, I&C and Nuclear designers.

   c. From the DTS data, determine the designer, engineering, clerical, management and other non-assigned, by DTS, manhours for each discipline for the total plant. These total manhours for each discipline are distributed among the direct three-digit accounts in proportion to the designer manhours.

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TABLE 9

PLANT CODE 148 | COST BASIS 01/84

UNITED ENGINEERS & CONSTRUCTORS INC.
EEDB-VII BASE COSTS (MEDIAN EXPERIENCE BASIS)
1139 MWE PRESSURIZED WATER REACTOR

12/10/84

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
21 .	STRUCTURES + IMPROVEMENTS	10,882,819	9046379 MH	179,034,156	92,926,613	282,843,588
22 .	REACTOR PLANT EQUIPMENT	221,460,014	4224696 MH	92,723,313	20,486,946	334,670,273
23 .	TURBINE PLANT EQUIPMENT	158,689,675	3066808 MH	66,820,106	10,762,311	236,272,092
24 .	ELECTRIC PLANT EQUIPMENT	29,494,445	2620099 MH	54,501,033	17,654,311	101,649,789
25 .	MISCELLANEOUS PLANT EQUIPT	16,076,802	1455031 MH	31,878,886	6,157,863	54,113,551
26 .	MAIN COND HEAT REJECT SYS	30,546,510	798587 MH	16,377,227	4,124,128	51,047,865
	TOTAL DIRECT COSTS	467,150,265	21211400 MH	441,334,721	152,112,172	1,060,597,158
91 .	CONSTRUCTION SERVICES	101,183,820	7282040 MH	152,922,760	99,073,870	353,180,450
92 .	HOME OFFICE ENGRG.&SERVICE	343,045,000				343,045,000
93 .	FIELD OFFICE ENGRG&SERVICE	337,331,840	903670 MH	18,977,770	16,477,600	372,787,210
	TOTAL INDIRECT COSTS	781,560,660	8185710 MH	171,900,530	115,551,470	1,069,012,660
	TOTAL BASE COST	1,248,710,925	29397110 MH	613,235,251	267,663,642	2,129,609,818

d. Develop HOE material related (specification, purchasing and expediting) hours for each direct three-digit account in the following manner:

$$p = \frac{a}{b} \quad (.25) \quad (c)$$

where: P = HOE related specification purchasing and expediting hours for each direct three-digit account

a = Factory equipment plus site material cost for each direct three-digit account

b = Total plant direct factory equipment plus site material cost

c = Total plant engineering and designer hours

The 25% of total plant engineering and designer hours is a relationship developed based upon UE&C experience.

e. Combine the hours in (1c) and (1d) above to provide total HOE hours for each direct three-digit account.

f. Divide the total HOE hours for each three-digit account by the total plant HOE hours to obtain the percent distribution of the total plant HOE cost. These percents are shown in Table 8.

g. Multiply the percents developed in (1f) above for each three-digit account by the total plant HOE (Account 92) cost for the EEDB-Phase VII, 1139 MWe PWR median case nuclear plant model. This provides a distribution of the Home Office engineering and service cost among the direct three-digit accounts.

2. Field Office Engineering & Service (Account 93)

a. The distribution of Field Office Engineering & Service (FOE) cost among the three-digit direct accounts is based upon direct craft labor costs and Home Office Engineering & Service costs.

Factors for distributing the FOE costs are determined as follows:

$$F = (2/3)\ (x) + (1/3)\ Y$$

where: x = Direct craft labor cost for each direct three-digit account

y = Direct three-digit account costs associated with the distribution of the HOE (Account 92) as determined in (1g) above

The (2/3) and (1/3) relationships were developed based upon UE&C's experience. These factors are shown in Table 8.

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b. The FOE cost was distributed among the direct three-digit accounts, as follows:

- o Divide the factor for each direct three-digit account by the total plant factor to obtain the percent distribution of the total plant FOE cost.
- o Multiply the percents developed above by the total plant FOE (Account 93) cost for the EEDB-Phase VII, 1139 MWe PWR median case nuclear plant model. This provides a distribution of the Field Office Engineering & Service cost among the direct three-digit accounts.

Home Office and Field Office Engineering & Service (Accounts 92 & 93)

a. Combine the distributed costs for HOE and FOE to obtain a cost distribution of the sum of these two components among the direct three-digit accounts. This combined distribution is shown in Table 8.

b. Divide the HOE and FOE cost for each direct three digit account by the total plant cost to obtain the percent distribution of the HOE plus FOE accounts cost.

3. Home Office Engineering & Service as a Percent of Direct Costs

a. Divide the distributed cost developed for HOE (Account 92) by the direct cost from the EEDB-Phase VII, 1139 MWe PWR median case nuclear plant model, at both the two and three-digit levels, to obtain the percent distribution.

6. NUREG/CR-3971 - New Construction

The final chapter of "A Handbook for Cost Estimating" provides a step-by-step working example of estimating the cost of providing a Technical Support Center (TSC) as an independent structure. This is construed as new construction since the structure is independent in the example problem. The handbook shows a direct cost of the TSC of 2.20 million dollars, excluding NRC costs, and Engineering/QA cost of 0.83 million dollars. The Engineering/QA content equates to approximately 38% of the total direct cost for the TSC.

The total direct cost, which consists of factory equipment, site material and craft labor costs, was obtained from functional responses (FR's) 18, 20 and 21 of the handbook. It was necessary to adjust the site material and craft labor costs, based on relationships obtained from EEDB-Phase VI, since they are shown as direct plus indirect costs in the FR's.

The Engineering/QA cost (Account 92) was obtained from a detailed analysis of all the FR's comprising the total TSC cost in the handbook. The Total Engineering/QA cost was first extracted from the FR's pertaining to the A-E costs and summarized. This total cost included both Home Office and Field Office Engineering and Service costs. It was necessary, therefore, to adjust it to include only Home Office Engineering and Service cost, by using a

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relationship from EEDB-Phase VI.

7. Data Summary

The above discussion of the various sources of data are summarized in Tables 1 and 1A.

The data in Table 1 compares the Engineering/QA cost, as a percent of the direct cost, for modifications to operating plants and new construction. The three sources of data for new construction, Tables 1A, 6 and NUREG/CR-3971, show good agreement where the median values for the Engineering/QA cost factors range from 29-38 percent. The four sources of data for operating plants, Tables 2, 3, 4 and 5, also show reasonably good agreement, although the Engineering/QA percents are lower than for new construction, as expected. The median values for the four sources range from 9-29 percent. The above ranges of median values for Engineering/QA percents typically apply to modifications entailing moderate to extensive structure/system changes or additions to the plant.

Although the range of all data for operating plants is rather broad as shown in Tables 2, 3, 4, and 5, this is not totally unexpected. There are cases where the Engineering/QA percents for certain modifications are greater than normally would be anticipated for operating plants. Modifications where structure/system changes are minimal, and a large amount of engineering analysis is required, are good examples of this case. Conversely, there are cases where the Engineering/QA percents for modifications are lower than normally would be anticipated for operating plants. Modifications, which consist of the installation of off-the-shelf items requiring a minimum amount of engineering, are good examples of this case.

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13 ABSTRACT (200 words or less)

This study provides generic estimates of engineering and Quality Assurance (QA) costs based upon the development and analysis of new and existing data. The estimates are cost factors, not absolute dollar values, expressed as a percentage of the direct cost of implementing the plant modification. These factors vary significantly depending upon the work environment at the time of the modification. Generally the work environment refers to two groupings of plants: the first relates to requirements affecting structures and systems already in place, while the second relates to new construction requirements which may be applicable to future plants, plants under construction, and/or operating plants. The types of modifications this study addresses are the physical modifications to the structures/systems of nuclear power plants as opposed to analytical or procedural changes. The derived estimates, when multiplied by the direct cost (i.e., equipment, material, and installation labor) or installing specific structures, systems, and pieces of equipment at a nuclear power plant will generate a reasonable order-of-magnitude estimate of the engineering Q/A costs associated with a physical modification.

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